

Combustion and Emission Analysis of Mahua and Jujube Biodiesel Blends as Fuel in a CI Engine

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Abstract— This present study on biodiesel blends shows the performance, emission and combustion characteristics of the DI diesel engine, which is been run independently on direct diesel fuel, 20% blending of zizipus jujbe methyl ester (ZJME20), and 20% blending of mahua methyl ester (MME20) with diesel. In this study, the tested fuels were obtained by catalytic transesterification process. Based on the experimental results, MME20 is favorable for less HC, CO, and smoke density than diesel and ZJME20. Based on the brake thermal efficiency and specific fuel consumption, MME20 is better when compared with ZJME20. The result also showed momentous improvement in the heat releasing rate due to the better performance characteristic of MME20.

Keywords— Mahua methyl ester, Ziziphus jujube methyl ester, Transesterification, Performance, Emissions.

I. INTRODUCTION

For many years, we are stuck or dependent over fossil fuels, which has provided us required energy, but they are finishing at higher rate, So we are forced to switch over to different renewable energy sources. Due to similar properties, biodiesel and their blends with conventional diesel to use as fuel in diesel engines [1]. Many researches have been conducted experiments using biodiesel in conventional diesel engines with minimum modification. It has been found that efficiency, brake thermal efficiency, emission characteristics and combustion characteristics are

almost dependent on the blends of the biodiesel with neat diesel [2-5]. After so many researches conducted on engine parameters like multiple injection, injection timing, compression ratio and injection pressure, and they concluded that for better performance, lower blending should be used, from B6 to B20, but it has been found that the engine gives the best performance of efficiency and other important properties with B20 mostly, after going through ASTM specifications, higher blending is not used because it requires appreciable engine modification to avoid certain maintenance problem [6]. Properties like eco-friendly, non-toxicity, and minimum sulfur content, makes biodiesel more attractive regarding production and use. Although, biodiesel has many disadvantages regarding performance as compared to conventional diesel like low calorific value, higher flash point, higher viscosity, poor cold fold properties, poor oxidation stability, and in some cases the higher NO_x formation, but efforts are going on to neglect these problems, it is also nothing as compared to what we had done to our environment till now and still continued. There are many methods to make biodiesel like transesterification, catalytic reduction, etc., But researches show that among these different methods, transesterification is better one due to its following advantages like less expensive, requires less pressure and temperature for producing biodiesel, less complex mechanisms, lesser time for production [7-11]. Mechanism of transesterification process is shown in figure 1.

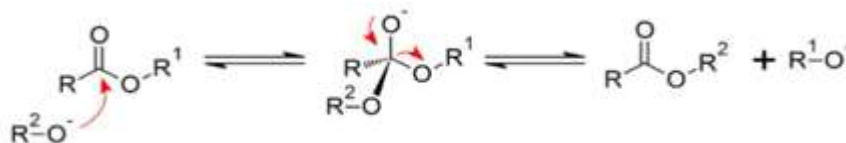


Fig.1: Mechanism of transesterification process (Source: CS Aalam, 2015)

From the literature, mahua and pongamia were chosen as potential biodiesel for this study [12,13]. In this work, the performance, emission and combustion characteristics of DI

diesel engine was analysed by mahua and pongamia biosiesel blends (20%) and found the suitable alternate blend for diesel engine.

II. TRANSESTERIFICATION

The reaction mechanism for alkali catalyzed transesterification was formulated as three steps. Transesterification is the process of conversion of the triglyceride with an alcohol in the presence of a catalyst to form esters and glycerol. Vegetable oil is subjected to chemical reactions with alcohol like methanol or ethanol in the presence of a catalyst. Since the reaction is reversible, excess methanol is required to reduce the activation energy, thereby shifting the equilibrium to the product side. The triglyceride present in the vegetable oil is converted into biodiesel. Among the alcohols used for the

transesterification reaction are methanol and ethanol. However, when methanol is processed, methyl esters are formed, whereas ethanol produces ethyl esters. Both these compounds are biodiesel fuels in different chemical combinations. The mechanism of transesterification reaction scheme is illustrated by Figure 2. Transesterification of rapeseed oil produces ester whose properties are comparable with those of diesel fuels. Schematic diagram of biodiesel plant is shown in Figure 3. The properties of the diesel fuel and the Java plum seed biodiesel are summarized in Table 1.

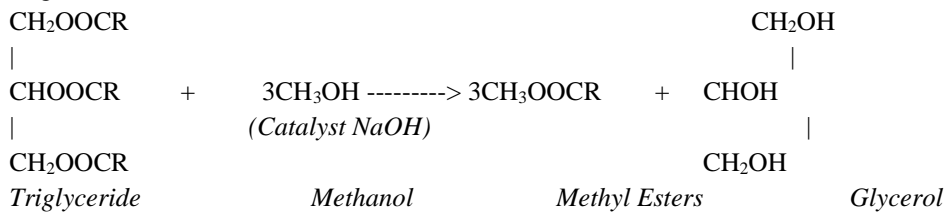


Fig.2: Mechanism of transesterification process

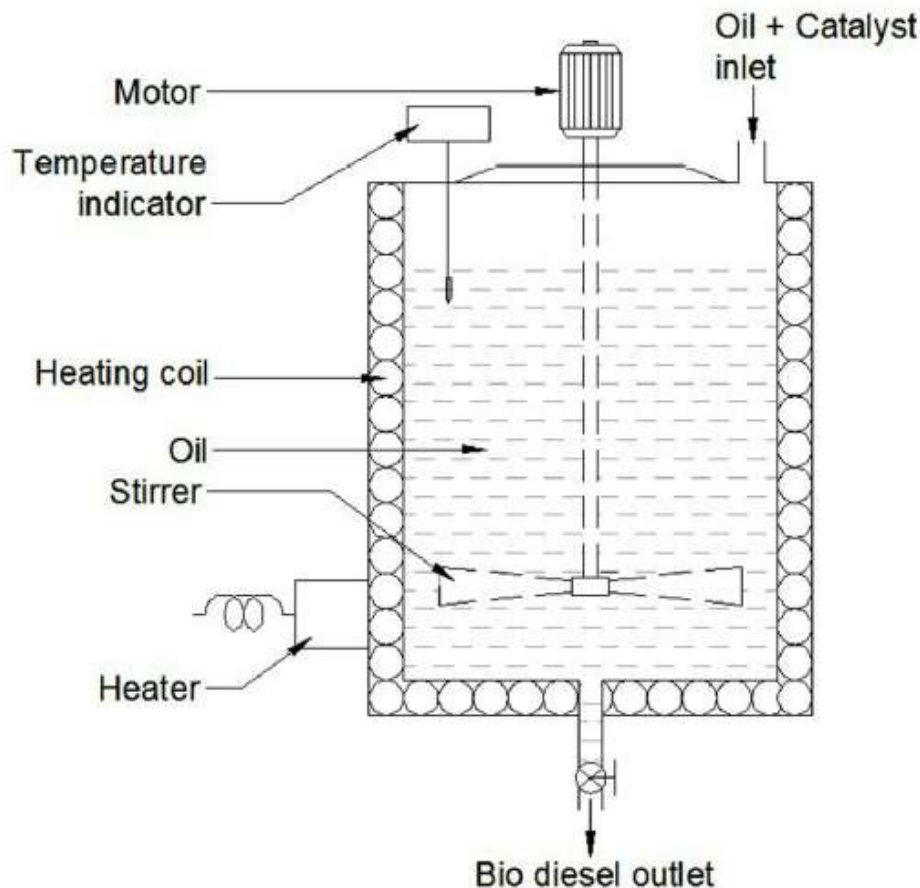


Fig.3: Schematic diagram of Biodiesel Plant

Table.1: Properties of diesel and biodiesel blends

Properties	Specific gravity@ 15/15°C (gm/cc)	Kinematic Viscosity @ 40°C (cst)	Flash Point (°C)	Fire Point (°C)	Gross calorific value (Kcal/kg)	Density @ 15°C (gm/cc)
Diesel	0.835	2.56	44	48	10,660	0.834
Mahua Biodiesel 100%	0.8846	5.1	77	89	9918	0.8861
Jujube Biodiesel 100%	0.8910	5.4	86	94	9452	0.8990

III. EXPERIMENTAL SETUP

The experimental investigations were conducted in a Kirloskar TV-I DI diesel engine. The specification of the test engine was given in Table 2. A single cylinder 4-stroke water cooled diesel engine with 5.2 kW brake power at constant of 1500 rpm was used in this study. The engine was coupled to an eddy current dynamometer with control systems. The engine is equipped with crank

angle sensor, piezo type cylinder pressure sensor, thermocouples to measure the temperature of the water, air and exhaust gas. Di-gas analyzer was used to measure the emissions like CO, HC and NO_x from the exhaust gas. AVL smoke meter was used to the measure the smoke density from the engine exhaust gas. The schematic view of the experimental setup was shown in the Figure 4.

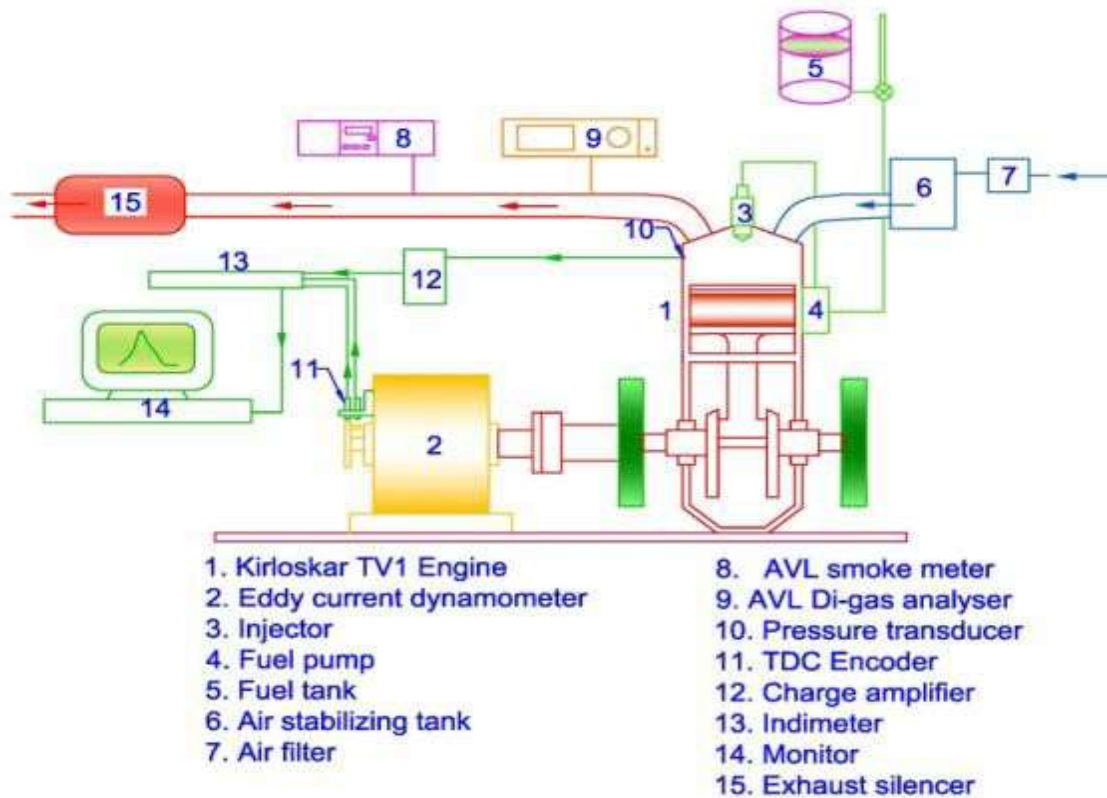


Fig.4: Experimental setup

Table.2: Engine Specifications

Type	:	Vertical, water cooled, four stroke
Number of cylinders	:	One
Bore	:	87.5 mm

Stroke	: 110 mm
Compression ratio	: 17.5:1
Maximum power	: 5.2 kW
Speed	: 1500 rev/min
Dynamometer	: Eddy current
Injection timing	: 23 (before TDC)
Injection pressure	: 250 kgf/cm ²

IV. RESULTS AND DISCUSSION

The experiment is carried out in the single cylinder, four stroke, water cooled diesel engine. The experiment is conducted with neat diesel fuel and with mahua and pongamia biodiesel blends (MME20 and PME20). Engine was found smooth through out the experiments and performance, emission and combustion characteristics of mahua and jujube biodiesel blends were compared with neat diesel fuel.

4.1 PERFORMANCE CHARACTERISTICS

4.1.1 BRAKE THERMAL EFFICIENCY (BTE)

Figure 3 shows the relation between Brake thermal and brake power. From the figure, it can be seen drastic changes of brake thermal efficiency at different Brake powers among all three fuels. These changes occur due to difference in properties of biodiesel blends and conventional diesel. Higher cloud point and appreciable cetane number as compared to conventional diesel provides the higher BTE to MM20. It can be seen that the brake power increases brake thermal efficiency also increases, which is highest in case MME20. The BTE was increased to 0.8 and 1.2% compared to diesel fuel in the cases of ZJME20 and MME20.

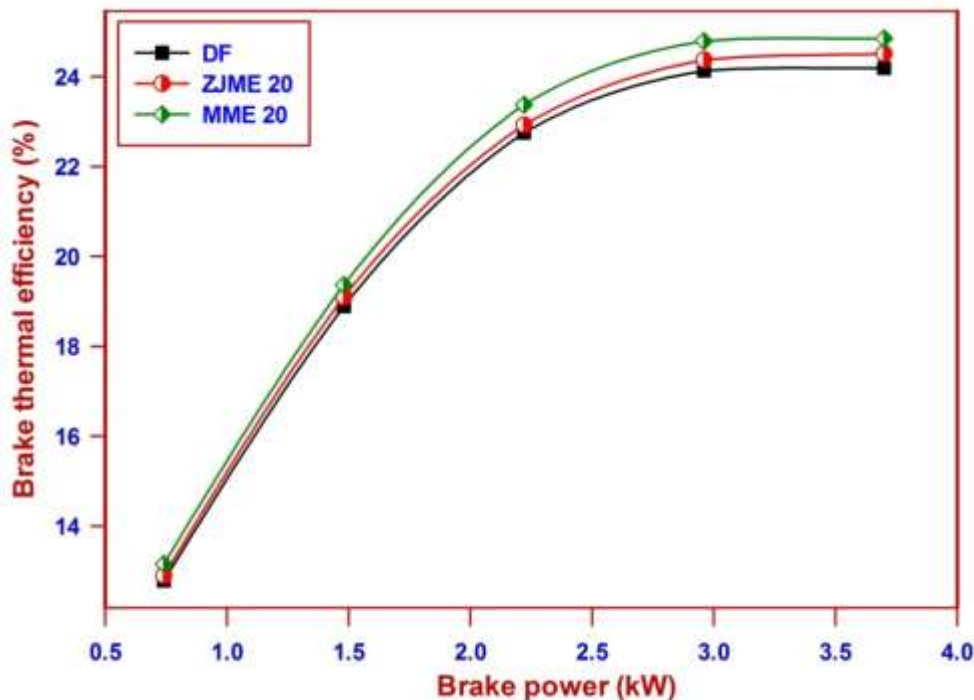


Fig.3: Brake thermal efficiency against brake power

4.2 EMISSION CHARACTERISTICS

4.2.1 HYDROCARBON EMISSION (HC)

Figure 4 shows the hydrocarbon emission with different brake power for MME20, ZJME20 and diesel fuel. From the graph, it can be seen that all the cases of brake power diesel produce more amount of hydrocarbon emission compared

with biodiesel blends. Due to higher viscosity and lower volatility of biodiesel affects the combustion of fuel during power stroke [4]. The hydrocarbon emission at maximum load was 118ppm, 112ppm and 104ppm for MME20, ZJME20 and diesel fuel respectively.

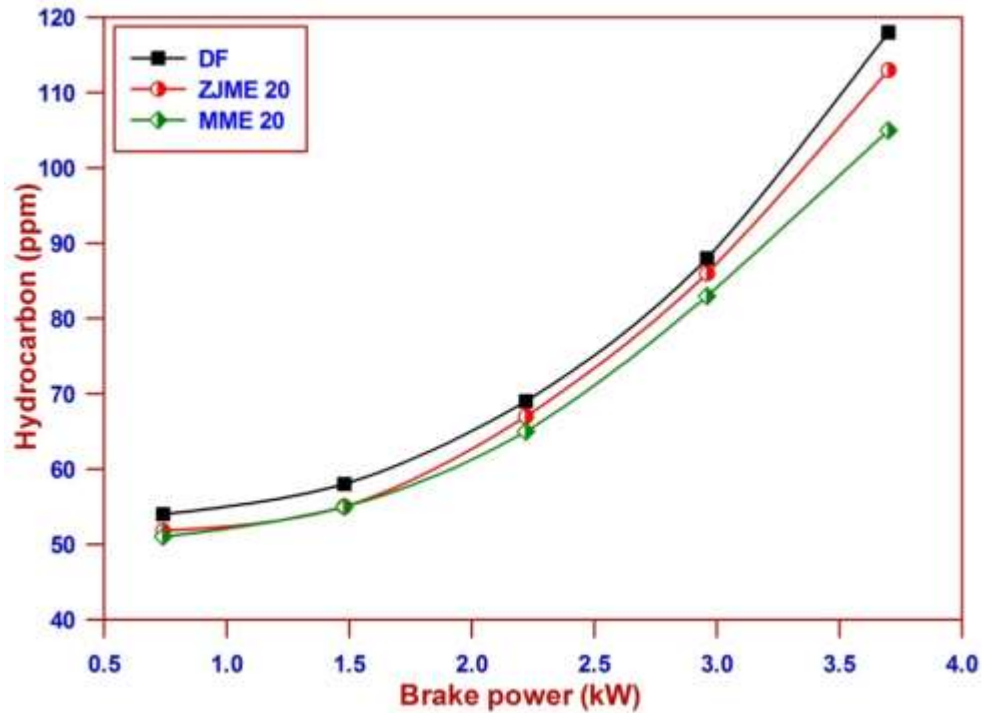


Figure 4 Hydrocarbon emission against brake power

4.2.2 CARBON MONOXIDE EMISSION (CO)

The variation of carbonmonoxide emission with brake power is shown in Figure 5. It is clear that at all brake powers, normal diesel emits more amount of CO as compared to ZJME20 and MME20. This is because of incomplete combustion of diesel fuel. The properties like

higher flash point, lower cloud point and higher cetane number of make this result possible. But among ZJME20 and MME20, MME20 holds top position because of better holding these above properties. MME20 is having a lower cloud point, higher flash point and higher cetane no as compared to normal diesel and biodiesel ZJME20.

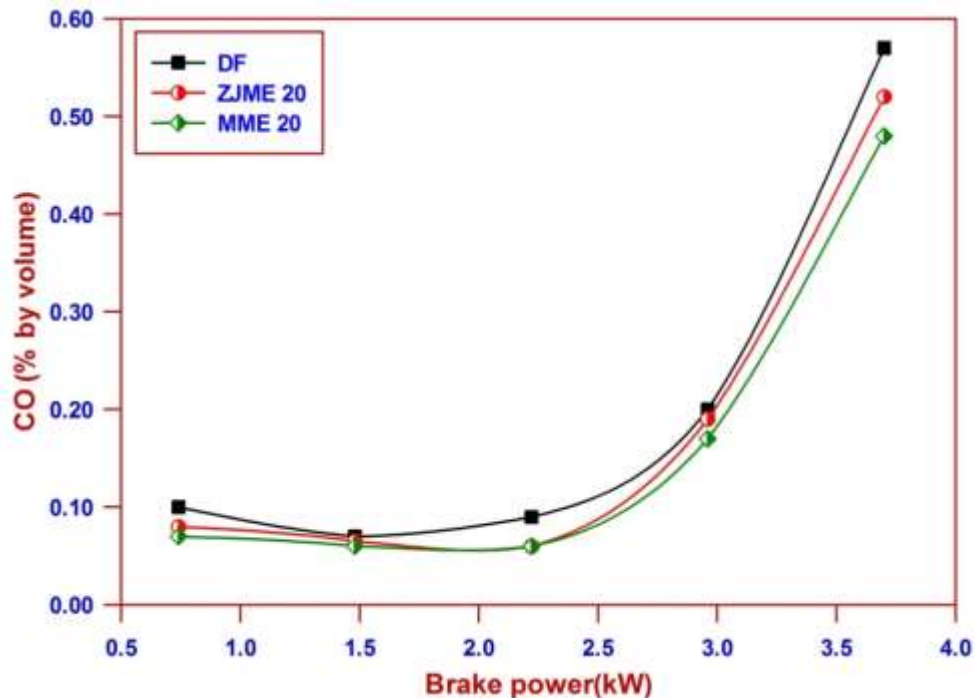


Fig.5: Carbon-monoxide emission against brake power

4.2.3 OXIDES OF NITROGEN EMISSION (NO_x)

The Figure 6 shows the variation between the brake power and oxides of nitrogen (in ppm) formation. Unfortunately biodiesel ZJME20 and MME20 behind race of less production NO_x. And it can be clearly seen that at each

value of brake power biodiesel produce more amount NO_x. As compared to normal diesel, which, is not required. This is because of biodiesel contains nitrogen in the form of proteins/amino compounds from their raw materials

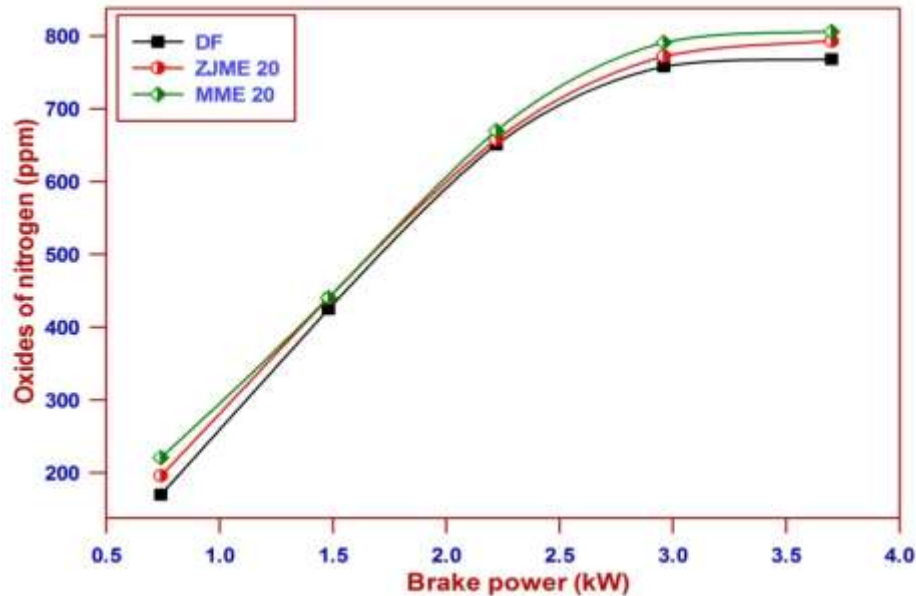


Fig.6: Oxides of nitrogen emission against brake power

4.2.4 SMOKE DENSITY

Smoke is one of the most hazardous problem with the engine, we always try to minimize this problem either by engine modification or by changing the fuel. Figure 7 shows that exhaust emission or smoke density with different brake powers of biodiesel ZJME20, MME20 and normal diesel. From the results it can be seen that each brake power, smoke

density is less in case of MME20 due to complete combustion of fuel, which in turn due to lower flash point and higher cloud point. By this graph it is also clear that biodiesel is able to combust properly with the same compression ratio with which normal diesel is not. So by this criteria MME20 is better.

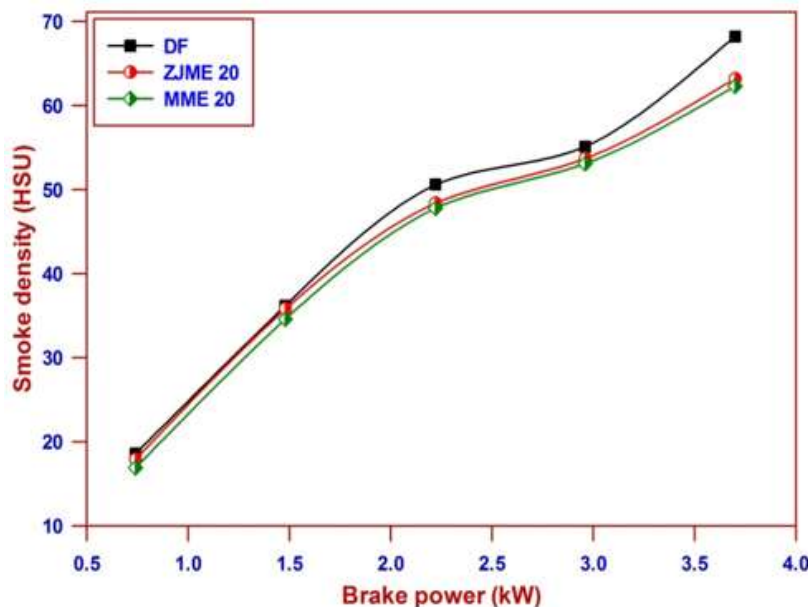


Fig.7: Smoke density against brake power

4.3 COMBUSTION CHARACTERISTICS

The Figure 8 shows the variation of cylinder pressure with different crank angle. It is clear at each crank angle the value of cylinder pressure is higher in case of biodiesel than the normal diesel. The higher production of pressure shows that the combustion of biodiesel takes place in a proper way. This is because of high volatility and better atomization than normal diesel. The Figure 9 shows that

production of heat with different crank angle. It is clear that at each and every crank angle Biodiesel acquires top position specially MME20. This is very useful because a larger heat production means a large amount of work produced thus large efficiency we get. Larger heat production is due to better combustion of MM20 than ZJME20 and normal diesel. High cetane number and lower flash point make this result possible.

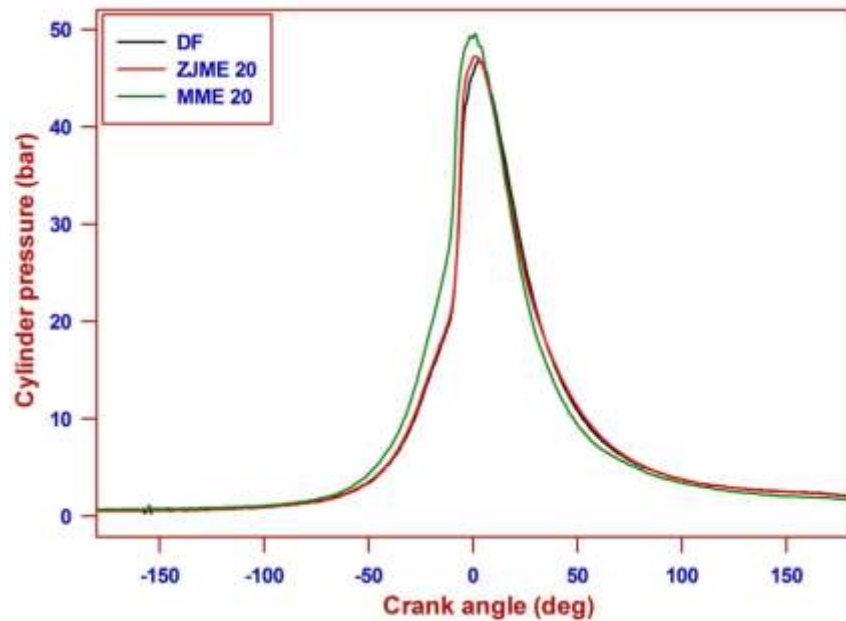


Fig.8: In-cylinder pressure against crank angle

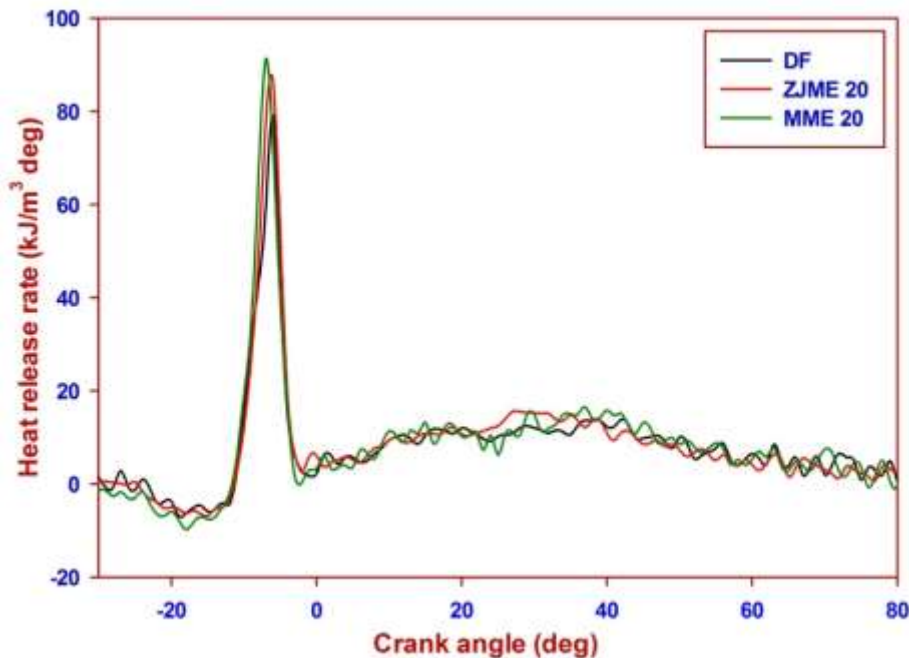


Fig.9: Heat release rate against crank angle

V. CONCLUSIONS

In the present investigation, mahua and jujube methyl esters fuelled diesel engine performance, emission and combustion characteristics were studied, and based on the experiments the following conclusions were drawn:

- Biodiesel blends have lower brake thermal efficiency, because of its inferior heating value. Compared with ZJME20, mahua methyl ester blend (MME20) has higher BTE.
- Mahua methyl ester blend (MME20) decreases HC and CO emissions up to 12% and 28% compared with a diesel fuel. NO_x emission increase with the use of biodiesel blends compared to the diesel fuel.
- The peak pressure decreases with the addition of biodiesel blends with diesel. The heat release rate also decreases with the addition of biodiesel. The properties like density and viscosity of biodiesel decelerate the hydrocarbon combustion and are the reason for the lower heat release rate when compared with neat diesel.

REFERENCES

- [1] C. Syed Aalam, C.G. Saravanan: Biodiesel Production Techniques: A Review. *International Journal for Research in Applied Science and Engineering Technology*, Volume 3, 2015, Pages 41-45.
- [2] C. Syed Aalam, C.G. Saravanan. Biodiesel Production from Mahua oil via Catalytic transesterification method. *International Journal of ChemTech Research*. Vol.8 (4), pp 1706-1709, 2015.
- [3] A.M. Ashraful, H.H. Masjuki, M.A. Kalam, I.M. Rizwanul Fattah, S. Imtenan, S.A. Shahir, H.M. Mobarak. Production and comparison of fuel properties, engine performance, and emission characteristics of biodiesel from various non-edible vegetable oils: A review. *Energy Conversion and Management*, Volume 80, 2014, Pages 202-228.
- [4] E.F. Aransiola, T.V. Ojumu, O.O. Oyekola, T.F. Madzimbamuto, and D.I.O. Ikhu-Omoregbe: A review of current technology for biodiesel production: State of the art. *Biomass and Bioenergy*, Volume 61, 2014, Pages 276-297.
- [5] Gaurav Dwivedi, M.P. Sharma, Potential and limitation of straight vegetable oils as engine fuel - An Indian perspective, *Renewable and Sustainable Energy Reviews*, Volume 33, 2014, Pages 316-322.
- [6] D.C. Rakopoulos, C.D. Rakopoulos, E.G. Giakoumis, A.M. Dimaratos, M.A. Founti, Comparative environmental behavior of bus engine operating on blends of diesel fuel with four straight vegetable oils of Greek origin: Sunflower, cottonseed, corn and olive, *Fuel*, Volume 90, 2011, Pages 3439-3446.
- [7] C. Syed Aalam, C.G. Saravanan, B. Prem Anand. Impact of high fuel injection pressure on the characteristics of CRDI diesel engine powered by mahua methyl ester blend. *Applied Thermal Engineering* 106 (2016) 702–711.
- [8] Dias JM, Alvim-Ferraz MCM, Almeida MF. Production of biodiesel from acid waste lard. *Bioresource Tech*, Vol. 100, Page 6355–61, 2009.
- [9] Kerihuel, A, Kumar, M. S., Bellettre, J., & Tazerout, M. (2006). Ethanol animal fat emulsions as a diesel engine fuel – Part 1: Formulations and influential Parameters. *Fuel*, Vol.85, No.17-18, (December 2006), pp. 2371-2684, ISSN 0016-2361.
- [10] Kamath HV, Regupathi I, Saidutta MB. Optimization of two step karanja biodiesel synthesis under microwave irradiation. *Fuel Process Tech*, Vol. 92, Pages 100-5, 2011.
- [11] Charoenchaitrakool M, Thienmethangkoon J. Statistical optimization for biodiesel production from waste frying oil through two-step catalyzed process. *Fuel Process Tech*, Vol. 92, Pages 112–8, 2011.
- [12] Lu J, Nie K, Xie F, Wang F, Tan T. Enzymatic synthesis of fatty acid methyl esters from lard with immobilized *Candida* sp. 99-125. *Process Biochem*, Vol. 42, Page 1367–70, 2007.
- [13] Salamatina B, Mootabadi H, Bhatia S, Abdullah AZ. Optimization of ultrasonic-assisted heterogeneous biodiesel production from palm oil: A response surface methodology approach. *Fuel Process Tech*, Vol. 91, Pages 441–8, 2010.